

ATTITUDE DETECTION METHOD AND APPARATUS FOR INITIAL MOTION CONTROL

FIELD OF THE INVENTION

The present invention relates, in general, to initial
5 motion control of moving a load over a predetermined path having
an attitude and, more particularly, the instant invention
relates to initial motion control of a powered door for a
vehicle, and yet, more particularly, the present invention
relates to initial motion control of a powered door for a
10 transit vehicle door system.

BACKGROUND OF THE INVENTION

The following background information is being provided to
assist the reader in understanding the environment in which the
invention will typically be used. The terms used herein are not
15 intended to be limited to any particular narrow interpretation
unless specifically stated otherwise in this document.

Examples of moving a load over a predetermined path which
also varies in a vertical direction, hereinafter referred to as
an attitude, include an apparatus for moving a work holding
20 table for metal cutting equipment, a powered apparatus for
moving a sliding door of a minivan, a conveyor for moving a load
between changing attitude levels, a powered accessibility device
for a transit vehicle, and powered door systems for transit
vehicles.

In many instances changing attitude levels may affect proper movement of the load if such attitude is not compensated for prior to the load movement. This is particularly the case in a transit vehicle which operates over various terrain attitudes
5 and conditions affecting door operation.

In a first aspect, a vehicle may be stopped on a terrain surface which is graded in a longitudinal direction, hereinafter referred to as a pitched attitude measured by a degree of pitch, affecting opening and closing of the doors that move parallel to
10 the vehicle structure. In such condition, when the door opening movement is toward the rear of the vehicle, the door will tend to open faster and close slower due to its own weight. When the door opening movement is toward the front of the vehicle, the door will tend to open slower and close faster due to its own
15 weight.

In a second aspect, the vehicle may be stopped on a terrain surface which is graded in a lateral direction, hereinafter referred to as a rolled attitude measured by a degree of roll, affecting opening and closing of the doors that move
20 perpendicular to the vehicle structure. In such condition, when the vehicle is rolled toward its side used for passenger ingress and egress, the door will tend to open faster and close slower due to its own weight. On the other hand, when the vehicle is rolled away from its side used for passenger ingress and egress,

the door will tend to open slower and close faster due to its own weight.

As would normally be expected, a much more severe condition for movement of the door is encountered when the transit vehicle
5 is stopped on the terrain surface which combines both roll and pitch attitudes.

In a third aspect, if a transit vehicle exhibits higher rolling levels due to lower tire pressure and/or wheel wear, a door of a larger size may obstructed against a stationary object
10 such as a curb or platform.

It is generally well known in the transit vehicle art to employ a door member engageable with a powered door operator and driven thereby to cover and uncover an aperture of the transit vehicle. The door is either attached to a driving means of a
15 stationerily disposed hanger member to achieve a sliding motion or to a pivotally disposed member to achieve a swinging motion. The powered door operators are either of electric, pneumatic or hydraulic types.

To expedite passenger ingress and egress and minimize a
20 dwell time of the transit vehicle at a stop, door opening and closing time intervals have been aggressively set in a 1 to 5 second range. Opening and closing door movements must be controlled in a manner providing smooth, continuous and accurate motion under all design and operating conditions and without

bouncing at either end of the movement. Additionally, in a transit vehicle having a multiplicity of door systems, all doors must open and close, for all practical purposes, within an identical time interval. These requirements are especially
5 challenging to meet with pneumatic type door systems due to inherent system response delays and pressure fluctuations of the air pressure supply.

Accordingly, it will be appreciated that a door control system must attain a certain level of precision in order to meet
10 the aforementioned requirements. Newer pneumatic or hydraulic systems may employ electronically controlled variable valves capable of modulating fluid pressure in order to achieve desired door movement. However, older and less sophisticated hydraulic or pneumatic control systems employ on/off discrete pressure
15 valve controls and thus lack the ability to respond to fluctuating operational parameters.

Newer microprocessor based control systems, especially for electric door operators, employ position feedback mechanisms and execute closed-loop motion control algorithms capable of varying
20 a motion profile over the range of the motion. A commonly employed motion profile is based on the velocity control using a well known trapezoidal profile. Such trapezoidal profile changes velocity in a linear fashion until the target velocity is reached. The profile consists of acceleration phase, constant

velocity phase and deceleration phase graphically representing a trapezoid. Closed-loop control systems compare measured output of the system with predetermined values and take corrective actions by varying velocity in order to achieve desired door
5 movement. Such comparison and corrective actions are performed throughout a substantial portion of the door movement, generally after the completion of the acceleration phase.

Alternatively, a position control, a torque control or a current control method may be used for door movement.

10 United States Patent No 6,064,165 issued to Boisvert et al teaches a method and apparatus for controlling motion of a motor driven element in a vehicle over a range of motion wherein a sensor continuously measures a motor parameter and each subsequent measurement is compared with the previous one to
15 determine its placement in a predetermined motion range. The values of the threshold parameter range vary with a position of the motor driven element over such range of motion or an elapsed time of movement. A controller coupled to the comparator alters the motion of the driven element if the measured parameter falls
20 outside of the range.

A disadvantage of presently used motion control methods is that the door accelerates and decelerates during the range of the motion to achieve a predetermined motion control profile and complete such motion in a predetermined time interval. Even

though door accelerations and decelerations may not be obvious to one observing door motion, they may decrease component durability by diminishing door movement with a constant speed value.

5 Such an approach further places additional constraints onto an obstruction detection algorithm executed by the control system as it now has to determine whether parameter fluctuations are due to obstruction or are due to other factors such as vehicle attitude described below.

10 The presently employed control systems lack a capability to recognize abovementioned surface attitudes prior to initiating door movement thus resulting in increased motion corrections during the range of the movement. This further affects the ability of the door to move within a predetermined time
15 interval, especially at the lower end of the range, and additionally affects movement synchronicity of a plurality of doors on the vehicle.

Another long felt need related to door system operation is the ability to recognize shock and vibration levels prior to
20 initiating door movement. Although this is the case in an opening direction, it is especially the case in a closing direction. Such shock and vibration levels increase the initial resistance to movement and further affect timing of the door movement.

As it can be seen from the above discussion, there is a need for door system attitude compensation prior to initiating door movement, especially for door systems that do not employ newer microprocessor controls.

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SUMMARY OF THE INVENTION

The present invention overcomes the aforementioned disadvantages of the present control systems by employing an apparatus for measuring a directional attitude of a driven load in respect to a level plane and for subsequently adjusting
10 initial driving power requirements in order to overcome the effects of such directional attitude.

An apparatus for accomplishing this includes at least one sensor capable of measuring directional attitude and providing a proportional signal. The sensor is disposed in a stationery
15 position in respect to such driven load and substantially aligned with an axis of the directional attitude. The operation of the sensor is enabled by a sensor power supply.

The proportional signal is received by a comparator or by a controller processor and is compared against a predetermined
20 threshold defining a level attitude to provide a drive signal.

The drive signal is then received by a driver which provides a control signal upon receiving a command signal initiating load movement. The control signal is used for

adjusting the initial driving power requirements to the load drive system.

Additional sensors measuring shock, vibration, speed or temperature may be employed for calibrating directional attitude measurements that are influenced by such factors.

Alternatively, these measurements may be employed independently or in combination with directional attitude measurements for further compensation of the initial driving power requirements.

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OBJECTS OF THE INVENTION

It is, therefore, one of the primary objects of the present invention to provide a vehicle attitude detection method and apparatus.

It is another object of the present invention to provide a vehicle attitude detection method and apparatus which operates prior to initiating door movement.

It is a further object of the present invention to provide a vehicle attitude detection method and apparatus capable of detecting a plurality of vehicle attitudes.

It is an additional object of the present invention to provide a vehicle attitude detection method and apparatus for use with pneumatic, hydraulic and electric door systems.

In addition to the various objects and advantages of the present invention which have been generally described above,

there will be various other objects and advantages of the invention that will become more readily apparent to those persons who are skilled in the relevant art from the following more detailed description of the invention, particularly, when
5 the detailed description is taken in conjunction with the attached drawing figures and with the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation of a sliding door type system for a transit vehicle;

10 FIG. 2 is a schematic representation of a swinging door type system for a transit vehicle;

FIG. 3 is a schematic representation of a bifold door type system for a transit vehicle;

15 FIG. 4 is a schematic representation of an outside sliding plug door type system for a transit vehicle;

FIG. 5 is a schematic representation of a slide-glide type door system for a transit vehicle;

20 FIG. 6 is a perspective view of a slide-glide type door system for a transit vehicle shown in a substantially closed position;

FIG. 7 is a schematic diagram of a first embodiment of the present invention;

FIG. 8 is a schematic diagram of a second embodiment of the present invention; and

FIG. 9 is a schematic diagram of a presently preferred embodiment of the invention.

**BRIEF DESCRIPTION OF THE PRESENTLY
PREFERRED AND VARIOUS ALTERNATIVE
EMBODIMENTS OF THE PRESENT INVENTION**

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Before describing the invention in detail, the reader is advised that, for the sake of clarity and understanding, identical components having identical functions have been marked where possible with the same reference numerals in each of the
10 Figures provided in this document.

The structure and operation of the present invention will be explained in combination with a powered door for a transit vehicle as use of the present invention in other applications will be obvious to those skilled in the relevant art form.

15 The reader's attention is directed to FIGS. 1 through 6, illustrating various types of door system geometry for at least partially covering and uncovering an aperture, generally designated 18, of a vehicle, generally designated 10. The reader will appreciate that operation of a sliding door system,
20 generally designated 20, in FIG. 1 will be affected by pitch attitude of the vehicle 10. When the front of the vehicle 10 is raised in a direction 24, a first door 22 of the door system 20 which moves substantially longitudinally within a door pocket 16 disposed between an outer wall 12 and an inner wall 14 will tend

to open slower in such direction 24 and close faster in a direction 28. A second door 26 will tend to open faster in a direction 28 and close slower in a direction 24. The reader will further appreciate that the above conditions will apply to a single type door 22, 24 covering portal aperture 18 or to a sliding type door system 20 disposed for movement external to the outer wall 12.

Operation of a swinging type door system, generally designated 30, in FIG. 2 and a bi-fold type door system, generally designated 40, in FIG. 3 will be affected by the roll attitude of the vehicle 10 as the movement of such swinging door system 30 and bi-fold door system 40 is perpendicular to the wall 12 of the vehicle 10.

Operation of an outside sliding plug type door system, generally designated 50, in FIG. 4 and slide-glide type door system, generally designated 60 in FIGS. 5 and 6 will be affected by a combination of pitch and roll attitudes of the vehicle 10 as these door systems move both perpendicular and parallel in respect to the outer wall 12 of the vehicle 10.

The structure and operation of the present invention will be further explained in combination with the slide-glide powered door system 60 for a transit vehicle 10 which is best illustrated in FIGS. 5 and 6 as those skilled in the art will

understand applicability of the present invention to other powered door systems.

The slide-glide door system 60 comprises a first door support member 62 pivotally attached to stationery portions of the vehicle 10 at first and second pivots 64 and 66 respectively and coupled to a first door 70 with at least one and preferably a pair of door guides 68.

A second door support member 72 may be pivotally attached to stationery portions of the vehicle 10 at first and second pivots 74 and 76 respectively and coupled to a second door 80 with at least one and preferably a pair of door guides 78. It will be appreciated that both the first door 70 and the second door 80 are disposed within the aperture 18 of the vehicle 10 for at least partially covering thereof and disposed adjacent the aperture 18 for at least partially uncovering thereof to enable passenger ingress and egress.

A door drive means, generally designated 90, is provided for moving the first door 70 and second door 80. Such door drive means 90 generally includes a drive member 94 rigidly attached either directly to the vehicle 10 or to a stationaryly disposed base member 92 which is, in turn, rigidly attached to the vehicle 10. A first link means 96 and a second link means 98 connect door drive means 90 with the first and second door support members 62 and 72 respectively in order to enable

movement thereof and, more particularly, enable movement of the first door 70 and the second door 80 in a closing and an opening direction. Alternatively, the first link means 96 and second link means 98 may be connected directly to the first door 70 and
5 second door 80 respectively.

It will be appreciated that the door drive means 90 can employ either an electric, a pneumatic or a hydraulic drive member 94 capable of generating a predetermined drive force. In further reference to FIGS. 8 and 9, the pneumatic and hydraulic
10 door drive means 90 further includes at least one control valve means 132 disposed intermediate such door drive means 90 and the power supply source 102. Additionally, a door controller 104 may be provided for both executing a motion control algorithm and for interfacing with the control system 140 of the transit
15 vehicle 10.

The essential element of the present invention is a stationaryly disposed vehicle attitude detection means, generally designated 110, best illustrated in FIGS. 7-9, which measures vehicle attitude values in at least one attitude
20 directional axis and processes such values to adjust at least one level of a power supply source 102 connected to the door drive means 90 prior to moving the first door 70 and the second door 80.

In particular reference to FIG. 7, the attitude detection means 110 includes at least one attitude sensor means 120 aligned with the attitude directional axis 106 or 107. The operation of the at least one attitude sensor means 120 is generally enabled by a sensor power source 116. The at least one attitude sensor means 120 is adapted for measuring a terrain attitude value in a predetermined directional axis 106 or 107 and providing at least one attitude proportional signal 122 to a comparator means 124 which interprets it against a predetermined threshold value which defines a substantially level attitude and is fixed in regards to the door position or movement.

The comparator means 124 then provides at least one drive signal 126 to a driver means 128. The driver means 128 then provides a control output signal 130 of at least one predetermined value to the door drive means 90 which enables first door 70 and the second door 80 to overcome vehicle terrain attitude disposition. The driver means 128 may further provide at least one directional feedback signal 127 to the comparator means 124 enabling thereof to provide a predetermined value of the at least one drive signal 126 proportional to the direction of door motion.

It will be appreciated that if the vehicle 10 is inclined in a pitch direction 106, as shown in FIG. 6, the second door 80, upon receiving at least one door command signal, which is a door

open signal 142 from a vehicle controller 140, will tend to open faster in the direction 106 and therefore the drive signal 126 will enable drive means 128 to issue at least one control output signal 130 of a first predetermined value to enable slower door opening. Upon preferably receiving a second door command signal, which is a door close signal, 144 from vehicle controller 140, the driver means 128 will issue a control output signal 130 of a second predetermined value enabling faster door closing in a direction 108 to overcome gravity factor.

When door drive means 90 is an electrical type, such at least one control output signal 130 may be pulsed with a modulation signal or a current level signal. In applications involving pneumatic or hydraulic door drive means 90, as shown in FIG. 8, such at least one control output signal 130 may enable a control valve means 132 to reduce fluid pressure 134 causing slower door opening and increase fluid pressure 134 causing faster door closing.

Preferably the at least one attitude sensor means 120 and the comparator means 124 are encased within an enclosure 121.

The at least one attitude sensor means 120 can be selected from a group of well known inclinometer technologies including but not limited to an accelerometer, a capacitive tilt sensor, an electrolytic tilt sensor, a gas bubble in liquid, a mercury

tilt sensor, and a pendulum which is a rotary shaft encoder coupled to a weight.

The at least one attitude sensor means 120 which is the accelerometer 120 may be selected from a group of well known
5 accelerometer sensor technologies including but not limited to a capacitance, an electromechanical servo, a resonating beam, a piezoelectric, a piezoresistive, a piezo film, a bulk micromachined piezoresistive, a bulk micromachined capacitive, a bulk micromachined resonating beam, and a surface micromachined
10 capacitive.

Those skilled in the art will easily understand that existing door system installations which lack sophisticated door controller 104 can be easily retrofitted with the attitude detection means 110 of the present invention.

15 In a new door system installation or in those installations which employ a sophisticated microprocessor based door controller 104, such at least one first proportional signal 122 from the at least one attitude sensor means 120 can be received by the processor 150 of the door controller 104 as best shown in
20 FIG. 9. Preferably, a processor 150 is adapted for providing at least one control output signal 152 which is substantially proportional to each incremental value of the at least one attitude proportional signal 122 thus enabling incremental initial control of the door drive means 90.

In the presently most preferred embodiment of the invention, the at least one attitude sensor means 120 is a surface micromachined capacitive multi-axis sensor 120 which is coupled to the processor 150 integral of the door controller 104
5 which is aligned with each of the attitude directional axis 106 and 107.

Those skilled in the art will readily understand that at least one sensor means 123 may be used to measure shock and vibration parameters acting on the door system 60 during at
10 least deceleration of the vehicle 10. It will be appreciated that if the vehicle 10 failed to reach a complete stop prior to the door system 60 operation, such door system 60 may require increased power supply levels from the power supply source 102 to overcome such vibration during opening.

15 The door system 60 may further experience vibration if the door closed command 144 has been issued in a close proximity to completion of the opening motion in response to the door open command 142. Additionally, the door system 60 may experience shock if the door close command 144 has been issued prior to
20 completion of the opening motion in response to the door open command 142.

Alternatively, the at least one sensor means 123 measuring shock and vibration may be employed as a calibrating means for

at least one attitude sensor means 120 in applications which require a close tolerance control.

Yet in another alternative embodiment, a temperature sensor means 125 may be employed to compensate for temperature effects
5 on such at least one attitude sensor means 120.

In another alternative embodiment, wherein the vehicle 10 failed to reach a complete stop prior to the door system 60 operation, at least one speed sensor means 127 may be adapted for measuring a speed of the vehicle 10 in order to compensate
10 for terrain attitude detection measured by the at least one attitude sensor means 120, which will be generally affected by such speed of the vehicle 10.

In applications requiring the at least one attitude sensor means 120 to be disposed remotely from the door system 60, such
15 at least one attitude sensor means 120 may be adapted with a transmitter 160 cooperating with a receiver 162 connected to the comparator means 124 to enable wireless communication of the measured terrain attitude.

In applications involving the sliding door 20 of FIG. 1,
20 the first and second door support members 62 and 72 respectively and drive means 90 will be adapted to enable substantially linear door movement.

In applications involving the outside sliding plug door 50 of FIG. 1, the first and second door support members 62 and 72

respectively and drive means 90 will be additionally adapted to enable a lateral door movement in respect to the outer wall 12 of the vehicle 10.

While the presently preferred and various alternative
5 embodiments of the instant invention have been described in detail above in accordance with the patent statutes, it should be recognized that various other modifications and adaptations of the invention may be made by those persons who are skilled in the relevant art without departing from either the spirit of the
10 invention or the scope of the appended claims.